Image-Based Rendering of Diffuse, Specular and Glossy Surfaces from a Single Image

Samuel Boivin and **André Gagalowicz**
MIRAGES Project

- **Main objectives of the paper**
  - Approximation of all reflectances using :
    - A single original image with no particular constraint for the viewpoint
    - A 3D geometrical model of the scene
  - Creation of a synthetic image keeping :
    - The real properties of the materials
    - The best visual approximation in comparison to the original image

- **Previous work in inverse rendering using global illumination and a full 3D scene (1/2)**

  - Estimation of perfectly diffuse reflectances
    - Single image :
      Fournier et al., GI’93 [14]
      Gagalowicz, Book 94 [28]
      Drettakis et al., EGWR’97 [11]
    - Multiple images :
      Debevec, SIGGRAPH 98 [7] (manually for non-di
      Loscos et al., IEEE TVCG’00 [24]

  ↳ Automatic reflectance recovery only for perfectly diffuse surfaces

- **Previous work in inverse rendering using global illumination and a full 3D scene (2/2)**

  - Full BRDF estimation (anisotropy)
    - Set of images:
      Yu et al., SIGGRAPH 99 [41]
      - 150 original images
      - Scene captures under specific viewpoints to compute BRDFs (capture of highlights)
    - Single image:
      None
      - This paper

SIGGRAPH 2001 EXPLORE INTERACTION AND DIGITAL IMAGES

- **Our method**

Data
- 3D geometrical model of the scene
- Objects are grouped by type of reflectance
- One single image captured from the scene

First Result → Reflectance approximation for diffuse, specular (perfect and non-perfect), isotropic, anisotropic, textured surfaces

Second Result → Synthetic Image imitating the original o (multiple possible applications)

• General overview of our technique

- Minimizing the error computed from the difference between the real and the synthetic image
- Choosing an hypothesis regarding reflectances

Enhancing as much as possible this hypothesis (maximal reduction of computed error)

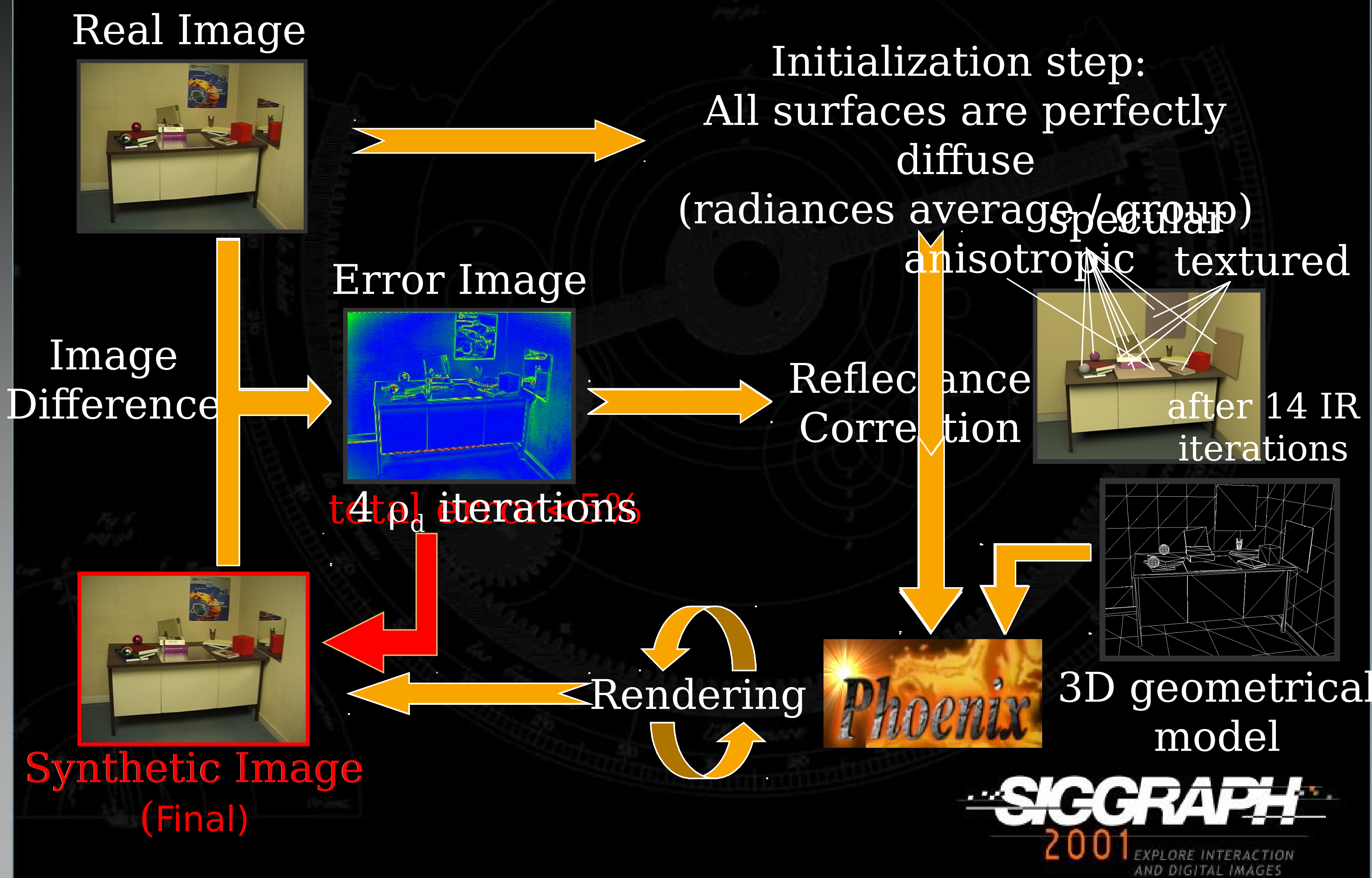
Iterative Principle

If the error is too big then change the hypothesis

Hierarchical Principle

SIGGRAPH 2001 EXPLORE INTERACTION AND DIGITAL IMAGES

- **Description of the full inverse rendering process**



- **The case of perfectly diffuse surfaces ($\rho_d \neq 0$)**
  - Average of the radiances covered by the projection of the group in the original image
  - Iterative correction of the diffuse reflectance ρ_d using this average value

    Computation of the error between the re
    and the synthetic image

      if error > threshold then
      group is perfectly specular

SIGGRAPH 2001 EXPLORE INTERACTION AND DIGITAL IMAGES

- **The case of perfectly specular surfaces ($\rho_s = 1, \rho_d = 0$)**

  - The simplest case because ρ_d and ρ_s are consta
  - Computation of the error between the real and the synthetic image

    if error > threshold then
    group is non-perfectly specular

- **The case of non-perfectly specular surfaces ($\rho_s \neq 1, \rho_d = 0$)**

  - Iterative correction of ρ_s minimizing the error between the real and the synthetic image
  - Computation of the error between the real and the synthetic image

Experimental Heuristic

if error > threshold then group is diffuse and specular

if error > 50% then group is textured

SIGGRAPH 2001 EXPLORE INTERACTION AND DIGITAL IMAGES

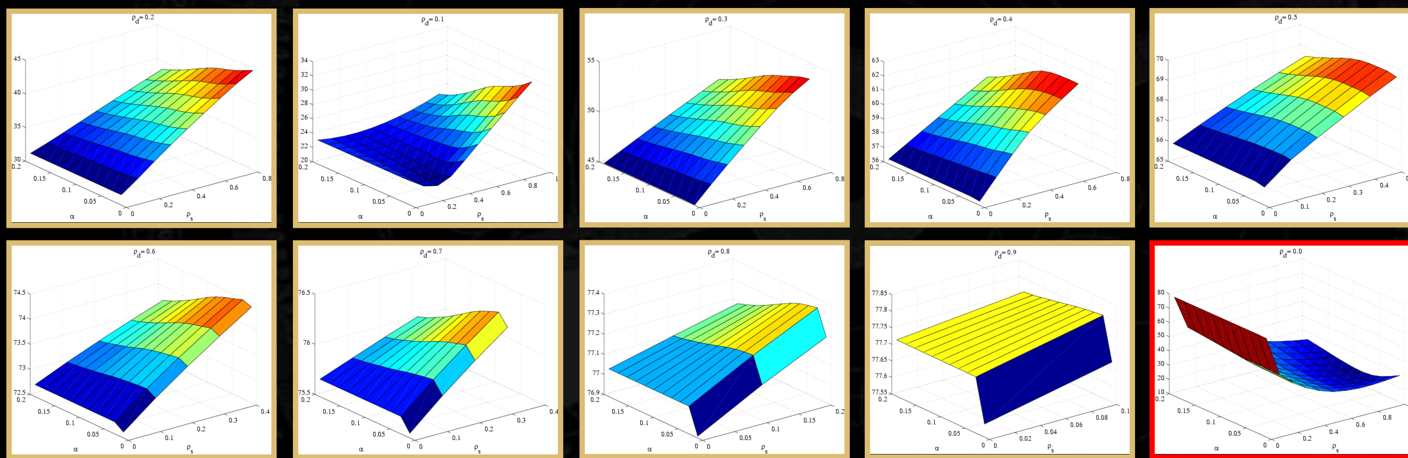
- **The case of both diffuse and specular surfaces ($\rho_s \neq 0$, $\rho_d \neq 0$, no roughness)**

  - Minimized error is a function of two paramete (direct analytical solution)
  - Computation of the error between the real and the synthetic image

if error > threshold then group is isotropic

- **The case of isotropic surfaces (ρ_d, $\rho_s \neq 0$, α)**

  - Direct minimization with ρ_d, ρ_s and α with $\rho_s = 1$ computed separately



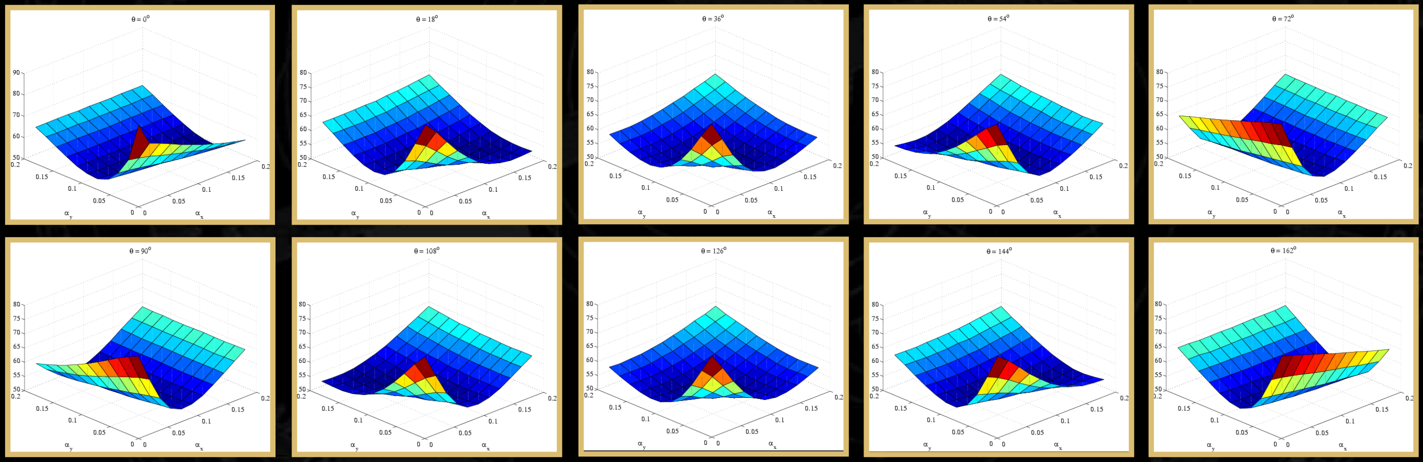
  - Computation of the error between the real and the synthetic image

    if error > threshold then group is anisotr

- **The case of anisotropic surfaces**

  $(\rho_d, \rho_s \neq 0, \alpha_x, \alpha_y, \vec{x})$

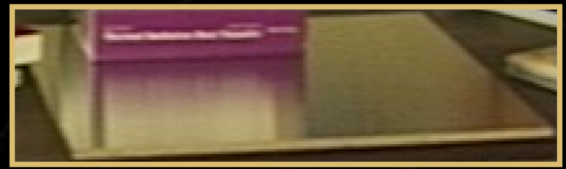
  - Minimization with $\alpha_x, \alpha_y, \vec{x}$



  - Several minima

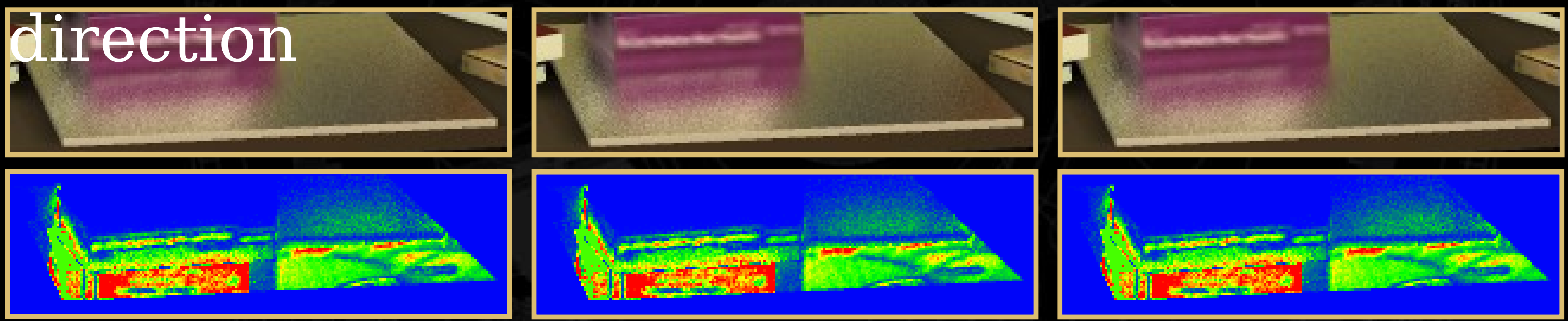
    → What are the resulting images ?

Original real image



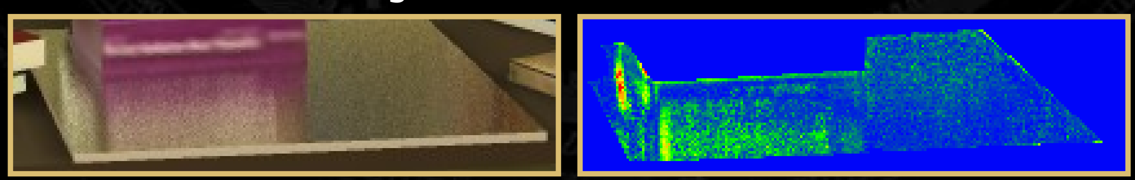
Synthetic images

without direct estimation of the anisotropic direction



unsatisfactory

with direct estimation of the anisotropic direction



- **The case of textured surfaces**
  - « Simple » because too few elements
  - Impossible to separate specular reflection and/or shadows from texture itself
  - Computation of an intermediate texture
    which balances the extracted texture
    (to take into account illumination)

- **Some inverse rendering results**

iterations

- **Some applications in Augmented Reality**

Illumination control

+ Geometry control

- **Conclusion**

  - New inverse rendering method

Advantages	**Disadvantages**
✓ One single image ✓ Various types of reflectances ✓ « Simple » idea ✓ Immediate extensions	▪ Textures are hard to take into account ▪ Particular cases (2 anisotropic surfaces)

Future Work

- Testing other BRDF models
- Solving the « texture problem » (2 images ?)
- Testing the algorithm using a scene under direct illumination conditions and/or with multiple colored light sources
- Automatic positioning of mirrors and light sources and adaptive meshing of objects
- Participating media (fire, smoke, …) using a new volume hierarchy (bounding volume)

SIGGRAPH 2001 EXPLORE INTERACTION AND DIGITAL IMAGES

- **Contact Information**

- Samuel Boivin (boivin@dgp.toronto.edu)

  Dynamic Graphics Project (Toronto, Canada)

- Andre Gagalowicz (Andre.Gagalowicz@inria.fr)

  INRIA (Rocquencourt, France)

SIGGRAPH 2001 EXPLORE INTERACTION AND DIGITAL IMAGES